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RANGE ECOSYSTEM RESEARCH

The Challenge of Change

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ABOUT THE FOREST SERVICE . . . . . .

As our Nation grows, people expect and need more from their forests—more wood; more water, fish, and wildlife; more recreation and natural beauty; more special forest products and forage. The Forest Service of the U.S. Department of Agriculture helps to fulfill these expectations and needs through three major activities:

- Conducting forest and range research at over 75 locations ranging from Puerto Rico to Alaska to Hawaii.
- Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our country's 395 million acres of State, local, and private forest lands.
- Managing and protecting the 187-million-acre National Forest System.

The Forest Service does this by encouraging use of the new knowledge that research scientists develop; by setting an example in managing, under sustained yield, the National Forests and Grasslands for multiple use purposes; and by cooperating with all States and with private citizens in their efforts to achieve better management, protection, and use of forest resources.

Traditionally, Forest Service people have been active members of the communities and towns in which they live and work. They strive to secure for all, continuous benefits from the country's forest resources.

For more than 60 years, the Forest Service has been serving the Nation as a leading natural resource conservation agency.

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FOREWORD

One characteristic of our times is change, and change brings with it challenges, opportunities, and problems. As we have looked forward to the 1970's, we have taken a new look at the Nation's rangelands and their importance to all segments of society. Half of the United States is rangeland, and as population, industrialization, and urbanization increase, rangeland's role expands. The economy of many localities and regions depends on range resources.

In meeting the challenge of the 1970's and adapting to changes in society's needs, what *is* the best way to proceed with research on the problems of managing, conserving, and using rangelands?

This publication outlines the direction we have chosen to take with rangeland research in the Forest Service, and explains the underlying philosophy. Our decision is based on the findings of a committee appointed in 1968 by the Chief of the Forest Service to: (1) make a critical review of range research; (2) consider society's changing needs for range resources; and (3) develop a comprehensive basis for research programs to meet those needs.

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SUMMARY

Society's needs and priorities are changing, and we need to take a new look at our concepts of rangelands. To replace the traditional land-use-based concept, the following ecologically based concept is proposed:

> Ranges are uncultivated areas that support herbaceous or shrubby vegetation.
>
> The range complex (ecosystem) includes not only the vegetation and soil, but also the associated atmosphere, water, and animal life.
>
> Most ranges are covered with native plants, but extensive areas have been seeded to exotics.
>
> Some areas are both range and forest: The tree overstory may be sparse, or the trees may have been harvested or burned allowing growth of herbs or shrubs.
>
> Rangelands have many uses and yield a variety of products. Livestock and game have been the most prominent, but other outputs are increasing in importance and are produced even by rangelands that are not grazed.

Rangelands make up half of our Nation's land area, and are an important part of our total environment. The widespread, diversified range resources include grassland prairies, brushlands, understory beneath open forests, desert areas, and other types.

Rangelands played a vital role in the economic development of the West, but early use of western ranges was unregulated, and pioneer stockmen generally knew little about the ecosystems. Overuse of the ranges damaged vegetation, soil, streams and lakes, and wildlife habitats. Range research and range management have helped to prevent new abuses and to repair damaged resources. The livelihood of many communities throughout the West, in the Ozarks, and in the South depends on rangeland.

Rangelands will become increasingly more important to society for various products and uses in addition to livestock. From a nationwide point of view, range livestock production is a modest part of total agriculture. Agriculture has become more specialized and more efficient, and crop and livestock production has shifted among the regions of the Nation. Western ranges have lost their comparative advantages for livestock production, while advantages have increased in the Ozarks and the South. America has millions of acres of surplus cropland on which livestock may be produced. Farm pastures and croplands will meet most of the future needs for additional livestock, although some of the future supplies may come from ranges, especially in the

South. Rangeland grazing, however, will continue to be an important part of the economic fabric of many localities and regions. Also, as sources of open space, natural beauty, recreation, water, clean air, and fish and wildlife, range values will increase.

Range ecosystems are composed of communities of plants and animals in their natural environment. Ecosystem components—vegetation, soil, water, air, fire, animals, topography, temperature, solar energy, and man—are closely and completely interrelated, and any influence on one affects others. Understanding the ecosystem is basic to all of man's goals for use of the natural resources.

Range ecosystems are important sources of a variety of outputs, including water, air, fish and wildlife, livestock, recreation, landscape and open space, miscellaneous other products, and a resource reserve.

Range ecosystems can contribute to present and future generations through the following societal goals: (1) maintaining environmental quality; (2) strengthening rural communities; and (3) providing recreational opportunities. We have a continuing obligation and privilege to efficiently manage and conserve the rangelands.

Livestock grazing will continue as one use of the land. Range livestock production, as the major economic base of many families, communities, and regions, can contribute to the economic stability and growth of rural areas.

Maintaining environmental quality in the rangelands includes conserving soil and water, maintaining range vegetation and open spaces as sources of oxygen and clean air, and preserving the quality of landscapes and scenery.

Rangeland areas, as sources of fish and wildlife, can produce more with proper management and investment. These lands, however, provide many recreational opportunities in addition to those based on wildlife and fish.

A comprehensive program is needed to develop information and data necessary for man to properly care for and use rangelands. Major research needs include:

- Analysis of ecosystems.
- Inventories of range resources.
- Coordination of management and use.
- Improvement of resources.
- Maintenance and improvement of environmental quality.
- Analysis of social and economic aspects of resource use.

RANGE ECOSYSTEM RESEARCH— THE CHALLENGE OF CHANGE

I. WHAT IS THE RANGE?

Customary concepts and definitions will not meet society's needs in the 1970's and beyond. The term "range," developed in the United States and until recently peculiar to this country (*58*),[2] traditionally carries a strong connotation of land used primarily for livestock grazing (*2, 37*). As society's needs and priorities change, rangelands are becoming increasingly important for additional uses and products.

An enlarged concept, based primarily on the ecological character of the land is more suitable for tomorrow's needs:

Ranges are uncultivated areas that support herbaceous or shrubby vegetation.

The range complex (ecosystem) includes not only the vegetation and soil, but also the associated atmosphere, water, and animal life.

Most ranges are covered with native plants, but extensive areas have been seeded to exotics.

Some areas are both range and forest: The tree overstory may be sparse, or the trees may have been harvested or burned allowing growth of herbs or shrubs.

Rangelands have many uses and yield a variety of products. Livestock and game have been the most prominent, but other outputs are increasing in importance and are produced even by rangelands that are not grazed.

This concept of rangeland will (1) serve as a foundation for strengthening our range research program, (2) help focus our research efforts on the most important problems of rangeland resource management, (3) provide us with a comprehensive approach, and (4) foster integrated interdisciplinary teamwork.

Much of the Nation's cropland has been developed from native rangelands. Most rangelands suitable for cultivation were converted to crop production or permanent pasture. Some areas have reverted to noncultivated status because of errors in selection, diminishing productivity, or economic changes. Often, an area is rangeland because its ecological nature, economic conditions, or lack of irrigation water make it unsuitable for cultivation (*8, 25, 38, 53*).

From an agricultural viewpoint, our present forests and ranges are economic residuals—areas left after the more productive sites were converted to high economic uses (*53*).

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[2] Numbers in parentheses refer to Literature Cited, p. 22.

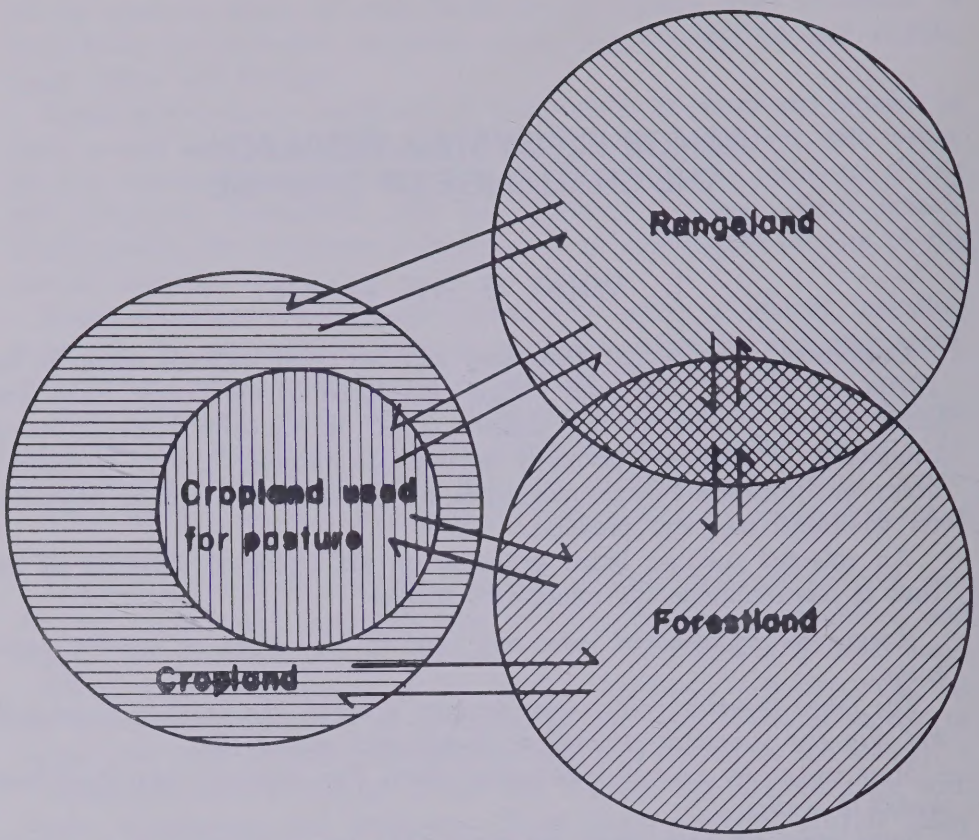

Figure 1.—Changes in ecological or economic conditions result in shifts in land use (see arrows) among rangelands, forestlands, and croplands. Some lands are concurrently range and forest. Not illustrated are the frequent shifts to urban and industrial uses.

Shifts among rangelands, forests, and croplands occur with changes in ecological or economic conditions (fig. 1). Some lands are concurrently range and forest. Croplands, rangelands, and forestlands have been, and will continue to be, transferred to urban and industrial uses as population increases.

Reliable information on the current extent of the Nation's rangelands is scarce. Available data, based on land-use concepts rather than resource characteristics (*16*), show that livestock graze 865 million acres (38 percent of the Nation's land area) in addition to cropland pastures. Not all rangeland is grazed, however, and it is estimated that half of the conterminous 48 States is rangeland as defined in this publication. Of the estimated total 908 million acres, grasses and shrubs are predominant on 653 million acres,

while 255 million acres are forested ranges. The estimated extent of the several types of rangeland in the 48 States is as follows:

	Acres (Millions)
Short grass	198.1
Sagebrush grass	96.5
Semidesert grass	89.3
Open conifer forests	87.0
Pinyon-juniper	75.7
Oak-hickory	57.0
Loblolly-shortleaf pine-hardwood	54.5
Pacific bunchgrass	42.5
Salt-desert shrub	40.9
Woodland-chaparral	31.0
Southern desert shrub	26.9
Longleaf-slash pine	26.5
Mountain grassland	25.0
Oak-pine	24.7
Tall grass	18.5
Alpine	8.0
Open aspen forests	5.0
Mountain meadows	1.0
Total	908.1

Grazing by wildlife and livestock has been the most commonly recognized use of range resources. As time changes, however, society is becoming more concerned about the total environment (*23, 33, 43, 44, 46, 51*), and is looking at rangelands from new points of view.

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Half of the 48 conterminous United States is rangeland.

II. RANGELANDS AND ECONOMIC DEVELOPMENT

Before the white man, millions of acres of grassland, shrub and woodlands, and open forest ranges provided food, cover, shelter, and space for wildlife. Settlers brought intensive agriculture, raw material-based industry, and an ever-growing population. As the frontier pushed westward, forests were cut, prairies were plowed, and large numbers of livestock were put on the rangelands. Resulting impacts on the environment often were severe *(22, 36, 49)*.

After the mid-1800's, large herds of cattle were pushed into the western range country, where free range forage created hopes of high profits and large capital gains *(31, 38, 49)*. Miners and farmers migrated westward, railroads extended their lines into the new frontier, and the cattle industry boomed.

When the free forage was all "spoken for," conflicts arose among competitors. For awhile cattlemen often agreed to divide the rangeland, but when homesteaders arrived, violent conflicts broke out between the "sodbusters" and the established ranchers *(36)*. Sheep and cattle wars erupted when sheepmen, also seeking free forage, invaded the range with large transient herds *(57)*.

Between 1870 and 1900, livestock grazing use on western ranges intensified, and the rangelands began to deteriorate *(49)*. Plant composition changed, productivity declined, streamflow was impaired, soils eroded, streams and lakes became silted, and wildlife habitats were damaged. Early stockmen knew little about the nature of these resources, and no institutional means existed to allocate scarce resources among competitors.

Public concern slowly but ultimately led to regulated grazing of publicly owned lands. This was a key step toward averting further impairment and toward repairing the damage already done.

The range livestock industry has contributed much to the economic development and growth of the West, and many western local and regional economies still rely on the use of rangelands for livestock grazing.

Although many native grassland ranges in the Plains and Prairie were converted to croplands, large sod areas still remain, and some croplands have reverted back to rangeland. Here, too, livestock use of rangelands promoted economic development, and rangeland grazing is closely integrated with crop production today.

In the Ozarks and in the South, use of rangelands for livestock grazing also has affected economic development. Some contributions are historically recent, and more rangeland-based growth and development are expected.

Range cattle production in the South gradually increased, as native grasses flourished after the pine forests were cut. Then, when the fever tick was eradicated in the 1930's, cattle population grew rapidly. Today, grazing of forested ranges is a primary component of rural economies in the South.

III. RANGELANDS AND THE FUTURE

The vast rangeland areas of the Nation are becoming increasingly valuable to society. Economic progress, changes in society's needs, and varying roles among regions are influencing the relative importance of several of the uses and products of the Nation's rangelands.

Relation to Agriculture

From the national viewpoint, livestock production on rangelands today is a modest part of total commercial agriculture (*12, 17, 18, 19, 26, 52, 54*). Although production of range livestock has increased some through the years, the rest of agriculture has improved and grown much more (*5, 30, 53*).

Agriculture in the United States has become more specialized and efficient. Shifts in crops and livestock production among regions reflect movements toward areas of greatest comparative economic advantage (*1, 20, 21, 40*). Some shifts in livestock production are directly related to improved technology for controlling shrubby vegetation. In the Midwest and on the Plains some croplands have been shifted from grain to livestock production. When cotton production shifted from the South to the Southwest, the South began producing more livestock.

The comparative advantage of cheap forage, once enjoyed by the western range livestock producer, has been lost through changes in consumer demand, production technology, land prices, and public land policies (*8, 18, 27*). Advantages have increased for the Gulf Coast and Ozark Regions, however, where State cattle populations now exceed those of many Western States (*1, 40*).

Increasing population and growing disposable incomes indicate that our Nation will need more livestock products. Some of the increased supply may come from rangelands, particularly in the Ozarks and the South. Most future needs, however, are likely to be met by farmers using some of the millions of acres of surplus croplands (*9, 18, 27, 28, 30, 45, 48, 53, 54*).

To consider rangelands only in terms of national agriculture is not enough. In addition to their vital role in local and regional economies, rangelands are sources of other uses and products, and are an important segment of our total environment.

Regional and Local Economies

The economic fabric of many areas in the West, the South, and the Ozarks is heavily dependent on use of rangeland for production of livestock (*3, 6, 14, 17, 18, 24, 26, 35, 52*). Rangelands have potential for strengthening local rural economies and for improving the economic welfare of rural families.

Other Products and Uses

Rangelands make up half of our Nation's total environment. As society develops a greater concern for environmental quality, it will recognize that rangelands are sources of open space, water, clean air, fish and game, recreation, and natural beauty (*8, 17, 18, 26, 27*).

A look ahead indicates the need for a comprehensive range research program that will (1) improve the economic and social health of range-dependent families, communities, and regions, and (2) maintain and enhance environmental quality.

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Ranchers and sportsmen enjoy the natural beauty and benefits of well-managed rangelands.

IV. RANGE ECOSYSTEMS: COMPONENTS AND PRODUCTS

The range is composed of communities of plants and animals in their natural environment. Variable and complex, rangeland has innumerable combinations of organisms, soils, and climatic and topographic features. These components function as an "ecosystem" which includes flow of energy and transformation, circulation, and accumulation of matter by living organisms.

Ecosystem is a term proposed by Tansley (*41*) to include both the living organisms of a community and the associated nonliving environment. Past attention has been focused on vegetation, but plants are merely part of the larger system, and vegetal response must be interpreted in terms of other components of the system and their interrelations (fig. 2). Ecosystem components are closely interrelated, and any influence on one affects others (*13*).

Despite recognition that the ecosystem functions as a whole, the maze of complex interrelations among the various biotic and abiotic factors has discouraged attempts at complete ecosystem studies. Nevertheless, studies of selected factors have contributed to our understanding of certain ecosystems. Recent developments in modeling concepts, mathematics, and computer technology, however, have opened the way to more complete ecosystem analyses.

Components

The several parts of the range ecosystem can be grouped into a few major categories.

Vegetation

Vegetation is the aggregate of plants—fungi, algae, mosses, herbs, shrubs, and trees. Range vegetation characteristically is variable, and even a small plot may contain numerous species. Hence, many different degrees of tolerance to other factors of the environment, a variety of growth forms, and many reproductive systems are represented in the range ecosystem.

Animals

Animals include man, domestic livestock, wildlife, and all fauna, both above and below ground. Historically, domestic livestock have had the greatest effect on rangelands, but pressures of wild animals also have been severe in many situations. Influences of grazing animals are exerted mainly through herbage removal, trampling, and dissemination of seed. Insects and rodents also can have tremendous effects on the range. Man is both a part of and a manipulator of range ecosystems (*55*). In reaching his production goals, man often has upset the ecological balance with disastrous results.

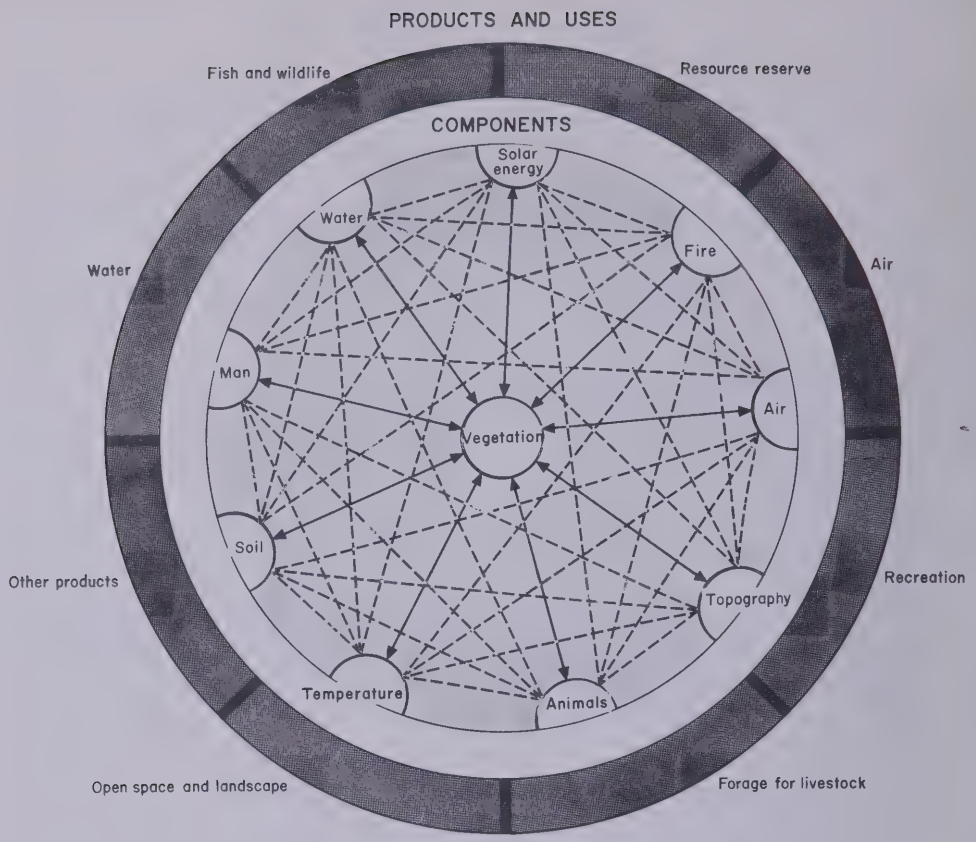

Figure 2.—The Range Ecosystem (adapted from Billings, *4*). Vegetation is related to other components (solid lines), and all components are interrelated (dashed lines). A wide variety of products and uses (outer ring) are provided by the range ecosystem.

Soil

Soil is the natural body of organic and mineral material that supports plant life. It varies with the parent material from which it developed and with associated climatic, topographic, and biotic factors. As the source of water and nutrients essential to growth of vegetation, soil is a basic resource that must be kept productive.

Topography

Topography, which includes the degree and direction of slope of the land surface, modifies local climate, helps determine the character of the vegetation, and influences distribution of animals.

Climate

Climate is a combination of atmospheric factors—radiation, precipitation, temperature, air, wind, and humidity–that helps dictate the type of vegetation and soil on a particular area. Variations in climatic factors make different kinds of weather, which greatly influence annual growth of vegetation.

Fire

Fire is considered a separate component of the ecosystem because of its unique effects. Starting from either climatic or biotic causes, fire has played an

important part in shaping the nature of major biotic communities and in determining their distribution. In some situations, fire can be a useful tool for ecosystem manipulation.

Water

Water is not only an essential component to maintain life and produce vegetation, but also is probably the most important product of the range ecosystem (see Products and Uses).

Products and Uses

The range ecosystem provides a variety of products and uses beneficial to society (see fig. 2).

Water

Water, probably the most important single product, is essential to human life, and is vital to the life and production of vegetation which may be harvested for man's use. Agriculture, transportation, power generation, manufacturing, waste disposal, and other of man's activities depend on water produced by rangelands and forest lands.

Total water requirements in the contiguous 48 States by 1980 are estimated to equal 50 percent of the renewable surface and ground water supplies, as contrasted to 21 percent in 1960. In some areas, present rates of use approach or exceed available water supplies (*45*). Rangelands comprise half the land surface of the Nation and play an important role in water production.

Air

Air—the mixture of gas, liquid, and solid particles that envelops our earth—is vital to man directly, essential for plants and animals, and necessary for man's domestic, community, industrial, and agricultural activities.

F-417433

The vast acreages of rangeland are important sources of water for urban, industrial, and agricultural use.

Physical properties of air—temperature, water density, and air movement—affect the growth and development of plant and animal life, and limit man's use of the land. Chemical constituents—oxygen, carbon dioxide, water vapor, and, increasingly, pollutants—directly affect man and his well-being (*29*).

Rangelands provide a source of unpolluted air as well as an immense capacity for receiving, and disposing of, pollutants from urban and industrial areas. Air quality is influenced by dust from wind erosion when soils are stripped of vegetal cover, by smoke from fires, and by the carbon dioxide-oxygen exchange process of vegetation. With increasing problems of air pollution, knowledge of the air environment and the contributions of rangelands become more important.

Fish and Wildlife

The Nation's rangelands and associated waters are the habitat for millions of big-game animals and countless numbers of other wildlife, including songbirds, upland game birds, waterfowl, and fish. These wildlife and fish provide a base for recreational opportunities and income for a broad spectrum of our population. For example, some 40 million people spend about $5 billion a year to go hunting and fishing. In addition, a great many people like to observe, photograph, or study wildlife. The economic impacts of fish and wildlife produced on rangelands are felt by many farms and rural communities.

Manipulation of vegetation through such practices as timber harvesting, livestock grazing, type conversion, selective plant control, and introduction of new species can greatly influence habitat quality and, consequently, wildlife populations. Interrelations between terrestrial range uses and associated fish habitats must be fully considered.

Livestock

Most range ecosystems produce vegetation that can be used as livestock forage. Public and private rangelands, with their long history of grazing use, are integral parts of the operations of thousands of families whose livelihood depends upon livestock (*8, 52, 54*). Range forage commonly is used in combination with hay, grain, pastures, and crop residues produced on adjacent croplands and allows profitable use of crops that otherwise might be difficult to market. This interdependence of range and farm resources is particularly true for some of the sparsely settled areas of the Plains and the West. Rangelands are a source of substantial numbers of cattle and lambs that are finished in feedlots prior to slaughter. Livestock grazing of most ranges is expected to continue for the foreseeable future. Rangelands must be managed to maintain or improve them while providing economic support to dependent families and communities.

Recreation

Rangelands provide recreational opportunities in addition to fishing and hunting (17, 26). The abundance of open space and interesting and beautiful landscapes is attracting more and more people to rangelands for camping,

F-410198

Sheep harvest the sparse forage produced on this desert range in Utah.

picnicking, rock hunting, and other outdoor recreational activities.

As a tool for managing landscapes, livestock grazing can stimulate wildflower production or alter the herbaceous growth in and around recreational areas. Quality recreational opportunities can be maintained and recreation can be integrated with other uses only when the land manager thoroughly understands the range ecosystem.

Open Space and Landscape

Open space and landscape *per se* contribute much more than recreational opportunities; their importance in the range ecosystem expands as society becomes more aware of the total environment *(43, 44)*. Ranges, with their diversified landscapes, are a large part of the Nation's open spaces.

Colorful rocks, unique geological formations, streams, lakes, and a wide variety of plant communities provide an endless array of interesting scenery for the traveling viewer. Wildlife also is a source of beauty and interest. To many, seeing wild animals in native habitats is the ultimate in enjoyment. Pastoral scenes also add to the landscape. Cattle, sheep, cowboys, sheepherders, rustic cabins, corrals, and sheep-camp wagons contribute to enjoyment of the range landscape—especially if good husbandry of land and livestock is evident. The broad expanse of open space where one's eyes and thoughts can roam to distant horizons is another valuable attribute.

Knowledge of the range ecosystem is essential to properly manage this resource, and to enhance and maintain environmental quality.

Other Products

Products from the range vary as much as its sites, climate, and vegetation. Ranges provide edible nuts and berries, chemical compounds with present and potential medicinal or industrial uses, and some wood products. Since livestock grazing and other land-management practices affect the vegetation and its various uses, management plans should account for all product possibilities from the range. The more we know about the ecosystem, the better we can manage the range and evaluate its various products and uses.

Resource Reserve

As an output of the range ecosystem, resource reserve is a national asset to be maintained in a condition of readiness to support our future growth and culture (*47*). Much more than a source of potential agricultural production, the resource reserve is a viable, flexible system that can respond to unforeseeable needs. The range resource reserve is particularly significant in

F-448140

Wildlife, an important component of range ecosystems, provides millions of Americans with sport and esthetic enjoyment.

F-512859

The open space associated with this alpine range in California enhances the landscape being enjoyed by these urban visitors.

view of our rapidly changing society. As population grows and our highly developed, progressive technology advances, more and more demands will be placed on our environment. We need to learn how to manage the range ecosystem to meet present demands without impairing its basic capacity to meet future needs.

F-483666

Trail riders enjoy ranges within the Pecos Wilderness Area in New Mexico.

V. RANGE ECOSYSTEMS AND SOCIETY'S NEEDS

Important goals for natural resource management in the United States during the 1970's are to:

- Maintain environmental quality.
- Strengthen rural communities.
- Provide recreational opportunities.

Rangelands can contribute to better living for present and future generations by providing security and stability for regional economies and rural communities, a high-quality environment, recreational opportunities, fish, wildlife, water, and forage for livestock. These uses, of course, must be balanced within the constraints of the stewardship responsibility.

Maintain Environmental Quality

As society concerns itself more with the quality of its environment, range ecosystems will assume a more important role as sources of open space, landscape, recreation, water, and clean air. Past uses and abuses of rangelands reveal a lack of harmony between man and his environment, often because man did not know how to manage the ecosystem:

- When livestock grazed the western ranges during the late 1890's the early settlers did not realize that too many cattle could severely damage the vegetation and cause soil erosion.
- When 18 million acres of mixed prairie in the Great Plains were plowed within a 10-year period, no one visualized the duststorms that were to follow.
- When chemicals were sprayed on millions of acres to control insects and noxious plants, the possible adverse effects on wildlife, birds, fish, or man were not anticipated.
- When water tables under some rangelands were lowered through gully erosion, no one anticipated the seriousness of the major vegetation changes that followed.

The science of range management has developed under a philosophy of stewardship—preventing damage to public and private resources, and restoring damaged rangelands (*34, 39, 49*). Scientific range management stands on the premise that vegetation can be used perpetually for grazing while simultaneously providing society with high-quality air and water, open space, and recreation.

Proper exercise of stewardship responsibilities will protect the ecosystem and its basic components from irrevocable damage. The total environment must be preserved, restored, or improved, as an obligation to future generations.

Conserve Soil and Water

Plant cover greatly affects amount, timing, and quality of water produced. Insect and disease infestations, wildfire, livestock and wildlife overuse, and severe droughts can seriously damage vegetation, reduce soil stability, and adversely affect water quantity and quality. On the other hand, man can manage the system to produce desired changes in vegetation with corresponding improvement in water yields and quality.

Some 4 billion tons of sediment are washed into tributary streams in the United States each year, and a substantial part of this comes from rangelands (*56*). Vegetation is the major deterrent to erosion. For example, amount of live plant and litter cover is the most important site factor affecting erosion on range types in Utah, Idaho, and Montana (*11*); this variable accounted for 52 to 80 percent of the explained variation in soil erosion. In Utah, a range watershed with 16 percent plant cover produced six times as much runoff and more than five times as much sediment as a watershed with 40 percent cover (*10*).

Livestock wastes can seriously impair water supply. Annually, domestic animals produce more than 1 billion tons of fecal and over 40C million tons of liquid wastes. In the United States, waste produced by animals equals that of 1.9 billion people (*56*). Manure disposal is difficult, partly because commercial fertilizer is less costly and easier to apply. Keeping livestock dispersed on pastures and ranges is one alternative that may help abate this type of pollution.

Maintain Clean Air

Rangelands provide one of the Nation's largest reservoirs of clean air. Vegetation on these vast areas is a vital source of photosynthetic activity. As plants extract carbon dioxide from the atmosphere, they release oxygen as a byproduct. This contribution to the oxygen-carbon dioxide balance is basic to life, and may be one of the range's most important, yet most overlooked, contributions to man's environment (*32*).

An estimated 30 million tons of dust enter earth's atmosphere each year (*56*). Windblown soil not only pollutes the air, but also lowers the quality of the land and its capacity to produce. Proper management of range ecosystems and repair and improvement of previously damaged rangelands can help alleviate this problem.

Preserve Open Space and Landscape Quality

Rangeland landscapes are rich in historical, archeological, scenic, and esthetic values. In his constant quest for open space and natural beauty, man can find freedom from disturbing noises, as well as from offensive sights and odors. Artists such as Remington and Russell have brush-captured the beauty of western rangelands. Music, history, literature, and photography of the deserts, mountains, and plains have created public awareness of the esthetic qualities of rangelands.

Resource managers are faced with the challenge of managing rangeland uses to preserve the beauty of the countryside, maintain and enhance the natural environment, and help satisfy the emotional needs of an expanding population.

Understanding ecological relationships among living things makes it possible for the land manager to conserve plant communities and animal life, and restore or maintain unique, diverse, and colorful landscapes. In Nicasio Valley, California, for example, environmental designers found that maintenance of the open grassland landscape requires continued moderate grazing or burning, mowing, or use of herbicides (*42*).

Strengthen Rural Communities

Many rural families, localities, and regions depend on income from rangelands. Although livestock products are the major source of income, recreational enterprises are growing in importance.

The social and economic viability of rural communities can be strengthened if (1) farm and ranch incomes can be increased to provide adequate returns to the operators, and (2) rural slum situations can be relieved. Correcting these two factors will help reduce the flow of rural people to urban areas in search of employment.

Rangeland is a major component of the income base for many farms and ranches, large and small, throughout the West, South, and the Ozarks. Rangeland use and management in these regions should be directed to provide adequate incomes, and maintain and strengthen the competitive position of families whose incomes and living standards are based on range livestock production. Opportunities exist for more efficient land use, better balance of resource combinations, improved efficiency of livestock production, increased volume of business, and lower costs of production for many range livestock producers.

Although livestock production always has been an economic mainstay of rangeland areas, some localities are experiencing new diversification. Recreational, fishing, and hunting opportunities are relatively new sources of local and area income for many rural communities. Benefits of these income sources can be increased if the ecosystem is understood and its management coordinated.

Several areas may be used as examples where range resources may be developed and used to overcome rural poverty.

A hypothetical case demonstrates the importance of rangeland to a western rural economy. If grazing were reduced 20 percent (222,876 animal-unit months) on Federal lands in Grant County, eastern Oregon, annual ranch income would decrease 11 percent ($405,000), and total county income would drop $624,000 per year (*6*). Comparable increases might be realized if range productivity were improved.

In the Ozarks and in the South, most small-acreage farmers depend upon grazing their livestock on forest ranges to augment their incomes. A socio-economic survey in east Texas revealed that median annual family income was $2,600, and that 57 percent of the families had incomes below the defined poverty level of $3,000 per year. Here, livestock production supplied more than 90 percent of the agricultural income.

One illustration of what can be done comes from the Ozark region where farmers strengthened their local economy and attracted new investment capital to their area. Low-quality hardwood forest areas were converted to grasslands,

and beef-producing farmers began realizing net returns of $15 per acre. Wooded land in the Ozarks was purchased for $40 per acre, converted to grassland at a cost of $20 per acre, and sold for $80 per acre. A lively market has developed for these lands.

Situations exist where effective improvement, management, and use of range resources might permit rural families to remain self employed and independent in their home communities; they could earn adequate incomes rather than move to a city where their presence might add to the urban crisis. Improved management and use of the 163 million acres of forested range in the South can strengthen and maintain rural families and communities.

Provide Recreational Opportunities

Recreational activities on rangelands have expanded from token, in pioneer times, to present-day major use. Clawson *(7)* estimated that city and country park-type recreation would quadruple by the year 2000, but resource-based recreation—visits to forests and rangelands—would increase fortyfold. This implies a need for more intensive and correlated management of rangelands for diverse products. Many ranges, now managed primarily for cattle and sheep, will be managed for wildlife as well, and game watching will be important along with hunting.

Nonconsumptive uses of rangeland environments such as photography, enjoyment of our historical rangeland heritage, and also viewing are important kinds of recreation.

Man, as a recreationist, exerts pressures on rangelands similar to those of grazing animals. Solutions to many recreation problems may be found in the time-tested principles used for range management. Rotation of campground locations is a short step from rotation of grazing use by animals. Concentrations of people and pack stock on fragile vegetation and soils are critical ecological problems.

Recreational values already are high for some rangelands, especially in the mountains. Those for other areas, such as deserts, are increasing. Generally, there need be no conflict between recreation and grazing if the two uses are properly managed.

Modern society values fish and wildlife more than did the pioneers who used them for food. Today, esthetic qualities outrank economic usefulness, and "harvesting" or "using" fish and wildlife includes personal observation and photography as well as hunting and fishing.

Managers of the range ecosystem must recognize the importance of the habitats for both fish and wildlife. Each species of big-game animals, small mammals, and birds has peculiar food and cover requirements. Interactions among wildlife species as well as interrelations of livestock and wildlife must be considered. Often, livestock grazing is *necessary* to maintain suitable wildlife habitats.

Streambank vegetation, trees, shrubs, and herbs regulate the amount of solar energy received at the stream surface. Water temperatures are critical for many species of fish. If streamside vegetation is damaged, water temperatures may shift and undesirable species of fish become dominant. Streamside vegetation also influences food production in streams and the chemical content

of the water. Condition of nearby watershed areas influences fish and their habitat. Sediment from roads, improperly used ranges, areas where plant cover is inadequate to control overland flow, and the streambanks that have been bared of vegetation can destroy fish habitats and populations.

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The awesome beauty of colorful landscapes is a source of pleasure to tourists as they traverse the open ranges of Arizona.

VI. RANGE-ECOSYSTEM RESEARCH

Public concern over rangeland stewardship and conservation problems fostered the growth of the art and science of range management *(34, 39, 50)*. Although the public recognized the need for resource conservation, the stockmen's contribution to regional and national growth could not be overlooked. Thus, range management concepts were developed to guide "planning and directing range use to obtain sustained maximum animal production, consistent with perpetuation of the natural resources" *(2)*. A program of range research was developed to provide a scientific basis for range management *(50)*.

Because of public alarm over mudflows, flash floods, excessive runoff, and siltation, early range researchers focused attention on watersheds damaged by unregulated and excessive grazing, as well as on fundamental ecosystem characteristics, improved grazing practices, and resource rehabilitation problems *(50)*. Range managers, research workers, and stockmen became involved in conservation efforts to the extent that some rangeland users felt that public stewardship goals conflicted with their own economic goals; that the rancher would have to forego production and income if the public was to have cleaner water, fewer floods, healthier vegetation, and other desirable environmental conditions.

Public interest demanded that range research programs be centered on the relationship between efficient livestock production and resource conservation. The resulting research findings showed that the rancher's livestock production increased at the same time the range improved, when he used conservation-type management and improvement practices.

Now, public attention is shifting to encompass much more than a range-livestock production relationship; maintaining a suitable environment for all segments of our society must be emphasized in our research efforts.

Range research problems can be grouped into the following categories:

- Analyze ecosystems.
- Inventory range resources.
- Coordinate management and use.
- Improve resources.
- Maintain and improve environmental quality.
- Analyze social and economic aspects of resource use.

Today, several agencies are conducting research on these problems. Among them are the Forest Service, Agricultural Research Service, and Economic Research Service of the U. S. Department of Agriculture, The Bureau of Sport Fisheries and Wildlife of the U. S. Department of the Interior, many State Agricultural Experiment Stations, and some universities, particularly those in the International Biological Program.

Although substantial progress has been made, the total research effort is far from adequate. Funds sufficient for a realistic research program, even as contemplated 30 to 40 years ago *(49)*, have not been available. The gap widens between knowledge available and that needed to exercise responsible management and stewardship of the range ecosystem.

Basically, the total range ecosystem research program needs to be expanded and its scope broadened to emphasize society's growing concern for environmental quality and improvement of rural communities.

The most pressing needs are for new information to: (1) help resolve serious problems confronting people and communities that are economically dependent on range resources, (2) facilitate more effective management of rangelands as a major portion of our total environment, and (3) permit meeting our stewardship responsibilities. Range ecosystems should be intensively and comprehensively analyzed, and rangeland resources scientifically inventoried.

Recent range research has focused on improvement of resources, coordination of management and use, and structure and function of plant communities; it should be continued and expanded. Research in the other categories limited by inadequate funds and by societal preferences, must be expanded and intensified.

Productive research on range ecosystems and man's use of them will require dedicated scientists with thorough and modern training in various disciplines such as soil physicists, micro-biologists, ecologists, range scientists, zoologists, mathematicians, economists, and sociologists. Some research problems will require interdisciplinary teams; others will require teamwork coordinated among groups of specialists. The traditional functional, or single-product oriented, research organization cannot cope with today's complex problems.

Analyze Ecosystems

Existing information on range ecosystems is substantial but incomplete and fragmentary. The scientific foundation for resource management in the 1970's is inadequate because the ecosystem components—vegetation, climate, topography, altitude, soils, air, solar energy—vary widely, their interrelationships are complex, and rangelands cover such a vast area—half our Nation. The first step, then, toward meeting society's goals, especially those for environmental quality and stewardship, is to consolidate our present knowledge and initiate new research.

The new research must be designed to identify the interrelationships within ecosystems, quantify and measure them, and determine which are most critical and which are most subject to manipulation. We also need to know more about the consequences of intervening in ecosystem processes. Some new work should be basic; some should be applied research, and yield models for evaluating alternative strategies of land management.

Inventory Range Resources

The national range resources need to be continuously inventoried and evaluated, and the rangelands characterized and classified, as a basis for

developing national policies and programs. Such an inventory would provide periodic data on quantity, quality, and productivity of range ecosystems.

Coordinate Management and Use

Multiple use management, often complicated, is essential to controlling environmental quality and strengthening rural communities. Systems are needed that minimize conflicts between wildlife and livestock grazing and other uses. Complementary uses should be encouraged. Managers responsible for multiple-use planning need to know the probable impacts of ecosystem manipulation alternatives on society's goals.

Improve Resources

Many ranges have been depleted because of unwise attempts to cultivate; past mismanagement of livestock; encroachment by undesirable shrubs and trees; and destruction by rodents, insects, or diseases. Low-value plants have invaded more than 300 million acres in the West; 40 to 80 million acres need intensive treatment to protect watersheds, improve landscape values, and restore forage productivity.

Maintain and Improve Environmental Quality

Man's use has often impaired the environmental quality of our rangelands. As population and use pressures grow, the threat of further loss of environmental quality increases. Research is needed to monitor undesirable changes imposed by management practices and uses; to determine impacts on soil, water, air, fish, wildlife, and recreational and landscape values; and to find ways to overcome prior damage and prevent future losses.

Analyze Social and Economic Aspects of Resource Use

Viable resource-use systems develop and operate within constraints imposed by social and economic criteria as well as ecological criteria *(15)*. A comprehensive range ecosystem research program should include work in the social and economic sciences. Too often, the lack of knowledge and understanding of the social, political, or economic environment of rangeland use has hampered, or even blocked, making full use of sound biological research.

Research is needed to provide a sound basis for directing ecological studies, and for getting their findings into practice. Social and economic research also is essential to efforts to maintain and strengthen rural economies.

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